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THE FUNDAMENTALS OF SPRAYING.

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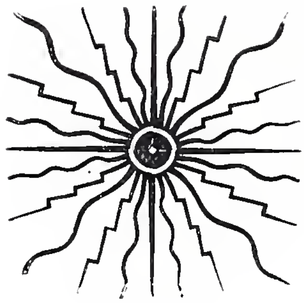

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THE FUNDAMENTALS OF SPRAYING.

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INTRODUCTORY.

Although the literature on spraying has become extensive since the introduction of the practice of treating trees and plants with insecticides and fungicides, there still remains much to be told to the ordinary grower of crops. In general, it may be said that the matter put forth has not been detailed enough. While the subject has been fully exploited so far as the desirability of spraying and the kinds of substances and compounds to be used are concerned, the many little points and details which go so far to make successful results possible have for the most part been overlooked in the effort to accomplish greater things. It will be the purpose of this bulletin to take up and consider the fundamentally important details of spraying, and attempt to explain the principles involved, so as to render it possible for the growers to think and act for themselves; thus enabling them to proceed intelligently and effectively in this important line of horticultural work.

Spraying is perhaps the most expensive of our orchard practices. For that reason it is very likely the most generally slighted of all horticultural operations. It is, on the other hand, the most exacting in its requirements. For without the most intelligent and painstaking care in every detail of the work, the efforts may lead not only to ineffective but even to negative results.

Importance of Timely Work.

In the first place the application must be timely. It will not do to put off spraying work until some other farm duties have been done, and then go out and squirt around in a hit and miss sort of fashion. The time when an insect or fungus can be successfully combated is, in most cases, exceedingly short. Often a difference of a day or two is sufficient to change success into failure. Thus in the case of codling moth, for example, it is impossible to reach the worm after it has gotten well into the fruit. As its first efforts are directed towards burrowing into the fruit, it is essential to have a poisonous dose on hand as soon as the worm is hatched. Moreover, *Slinger-

*Cornell University Experiment Station Bulletin 142, p. 21.

land has shown that most of the insect's feeding before it enters the apple is done in the calyx cavity between the calyx lobes, where from 75 to 90 per cent. of the worms go in. It is important, therefore, to have the calyx cavity well charged with poison. Formerly it was supposed that this could be accomplished at any time before the young fruits turned down. Slingerland* has pointed out the fact that the calyx lobes of the young apples close over the cavity in from seven to ten days after the blossoms fall. (See Plate I.) After such closing, it is practically impossible to get the poison into the cavity. The importance, then, of completing the application before the closing takes place is emphasized. To the owners of large orchards this is especially important, for it means that sufficient apparatus must be provided to enable the spraying of the entire place before the expiration of the period mentioned. So it is also with the great majority of fungous diseases: It is impossible to reach them when once they have penetrated the skin, as will be explained later.

General Classes of Mixtures.

There are two general classes of spray mixtures, viz:

1 Insecticides.

2. Fungicides.

The first class includes all mixtures used for the destruction of insect pests; the second includes all applied against fungous diseases.

Classes of Insects.

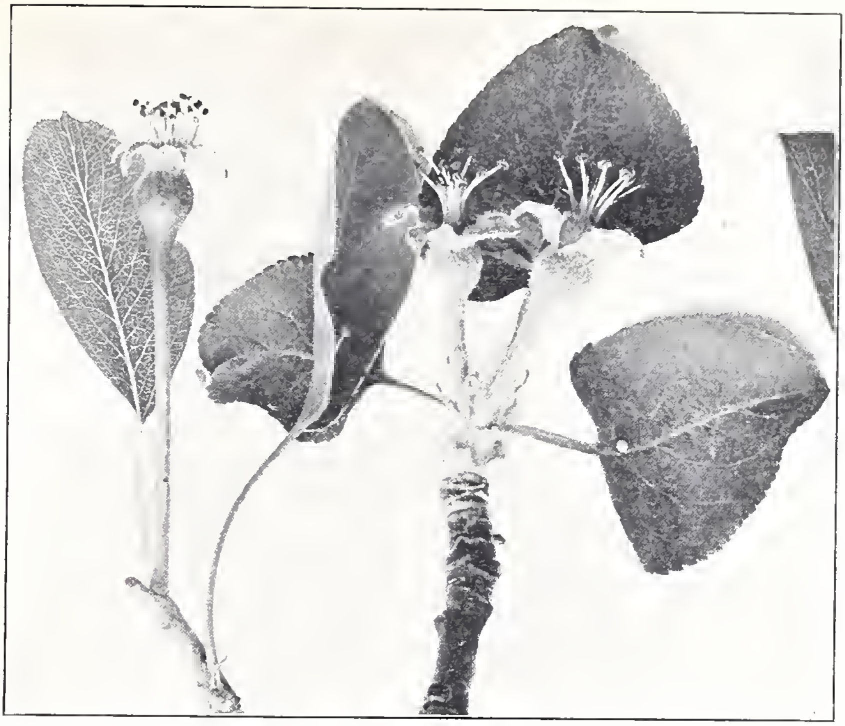
Every fruit-grower or farmer knows what an insect is. But not every fruit-grower or farmer knows that the insects attacking fruits and plants are of two general kinds They are; and the two classes are as follows:

1. Chewing insects, or those which have biting and chewing mouth-parts. These take in and digest solid food, usually the leaves or fruit of plants. Such are, for example, the codling moth, canker worm, web worm, tent caterpillar, leaf skeletonizer and the like.

2. Sucking insects, or those which have sucking mouth-parts. These suck the juices of the plant and therefore live entirely upon liquid food. These are the plant lice, scale insects and the like.

Naturally, then, the life habits of these classes of insects demand very different methods of spraying in order to destroy them. The first class can be reached through their food supply, and are, therefore, easily destroyed by poison eaten along with the parts of the plant attacked. The second class cannot be reached through their food supply, as they derive their sustenance by sucking the juices from within the plant tissues. They can, therefore, be destroyed only by contact with some caustic or suffocating compound. There are, therefore, two classes of insecticidal sprays:

*Cornell University Experiment Station Bulletin 142, pp. 54 and 55.



(a) A pear and two apples just right for spraying, the calyx lobes spreading and open, just after the petals have fallen.

(b) One week after the petals have fallen. Almost too late to spray the apples, the calyx lobes having almost completely closed over the cavity. The middle fruit is that of a pear, which closes little, if any at all.

PLATE I.

Apples just after the petals have fallen and one week later.

(From photographs by Slingerland, Cornell Experiment Station, Bull. 142, pp. 54 and 55.)

(a) Before germination.

(b) During germination.

PLATE II.
Bitter Rot Spores, as seen under the Microscope.

Poison sprays, such as Paris green, arsenite of copper, arsenite of lime, arsenate and arsenite of lead, and arsenical poisons generally. These are effective against the first class of insects only.

Contact sprays, such as kerosene, crude petroleum, the lime, salt and sulphur wash, whale oil soap, rosin wash, pyrethrum, and tobacco. These kill the insects by their caustic action or by closing up his breathing pores and thus suffocating him. The second class of insects can be destroyed only by these. Insects of the first class may also be destroyed by contact sprays, but only in rare cases is this class of mixtures so employed.

Fungi.

In order to understand fully the action of remedies against the other class of enemies which the fruit-grower has to combat, the fungi, it will be well to consider somewhat in detail the definition of a fungus—just what it is, how it lives and grows.

What is a Fungus?—A fungus is first of all a plant. It belongs to a lower order of plants, differing essentially from the more familiar "higher" plants in possessing no chlorophyl, or green coloring matter. It is incapable of assimilating inorganic (mineral) substances, and is therefore dependent upon organic matter either living or dead, upon which it grows and derives its sustenance just as the higher plants derive theirs from the soil. It has no leaves, but it has something akin to roots and stems, the mycelium, and its means of reproduction and spread, the spores, analagous to the seeds of higher plants. The spores are perhaps the most important part of the fungus from the point of view of the fruit-grower, for it is by the means of these that the disease or destruction by the fungus is spread from leaf to leaf, from fruit to fruit, or from tree to tree. Any agency, then, which may disseminate the spores may be the means of spreading the disease caused by the fungus. Wind, rain, insects, birds, animals and even man himself are known to act in this capacity.

How a Fungus Grows.—Now, what takes the place when one of the spores falls or is placed upon a leaf or a fruit? If the conditions of temperature and moisture are favorable it will germinate—just as a seed does when planted in moist, warm earth—and send out a small tube, known as the "germinating tube" of the fungus. These spores with their germinating tubes are exceedingly small and can be seen only with a compound microscope. Plates II *(a)* and II *(b)* are reproduced photo-micrographs of bitter rot spores before and during germination, all greatly enlarged. From this point fungi differ in their development, in the manner in which they grow and extract their nourishment from the parts of the host plant attacked. In one class the germinating tube

begins to branch out and continues growing upon the *surface* of the leaf or fruit, leaving its mycelium exposed. These are known as external fungi, and are by far the easiest class of fungous diseases to combat. (See Fig. 1.) For it is obvious that the fungicide can be applied directly to the mycelium. In this way the fungus can be destroyed and its further development prevented. To this class of fungi belong the powdery mildews of the grape, the gooseberry and the rose.

In the other class of fungi, the internal fungi, the germinating tube penetrates the skin and there branches. Thus the mycelium is developed within the tissues of the parts of the plant attacked. (See Fig. 2.) It is obvious, then, that the mycelium is wholly out of reach of any spraying compound, and, therefore, once the fungus has gained entrance it is practically impossible to arrest its development. The remedy can be only preventive in its action. The fungus must be killed before the germinating tube enters, otherwise all effort is lost. This is so fundamentally important that it will bear the strongest emphasis. In addition to this it must be pointed out that the most commonly used fungicide, Bordeaux mixture, does not destroy the spores themselves. It is the little germinating tube only which is destroyed by the fungicide, and, therefore, before the remedy can be effective, the spore must germinate. Hence, the necessity of having the remedy applied in time becomes doubly important, for the germinating tube must be destroyed before it penetrates. The dedevelopment of the disease will continue, despite the presence of the remedy applied too late, and complete its life history by producing new crops of spores ready to spread the disease anew. The downy mildew of the grape, the scab, the fruit rots, the cankers—in fact, most of the fungous diseases which afflict trees and plants in this region of the United States come under the head of internal fungi, and must be dealt with accordingly. Remedies should be applied before the fungi of this class have gained a firm foothold. Spraying should be begun upon the first appearance. It is not necessary to wait for it to make a "showing." Otherwise, the spores may become so extremely abundant that, relatively, a large proportion of them may escape the fungicide and thus complete their mission of destruction.

Classes of Fungi Summarized.

To summarize briefly, therefore, regarding fungi, it is seen that there are:

External fungi.—powdery mildews of grape, rose and gooseberry —which develop on the surface or outside and which are thus comparatively easily killed at almost any stage of their growth by fungicidal mixtures coming in contact with their exposed mycelium. (Fig. 1.)

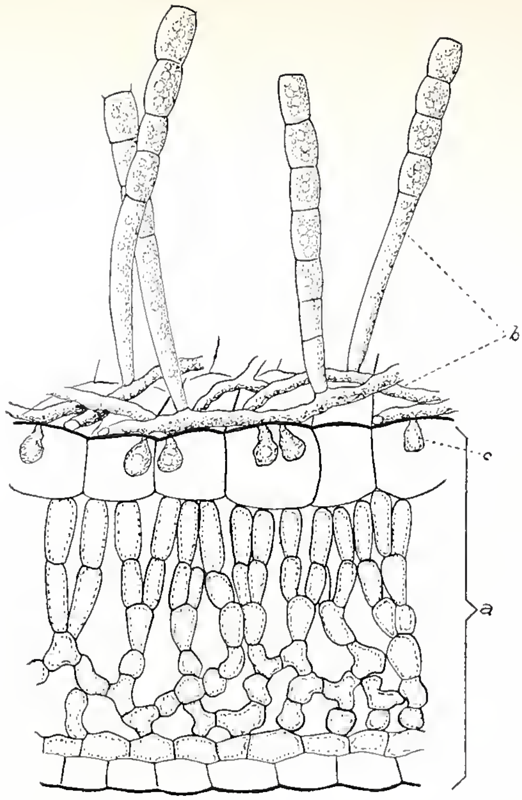


Fig. 1. Greatly enlarged cross section of rose leaf (a) affected with an external fungus, the powderly mildew. Both the mycelium and spores (b) are entirely external. The fungus sends suckers (c) into the epidermal cells to get nourishment.

(Drawing by H. Hasselbring of the Illinois Experiment Station.)

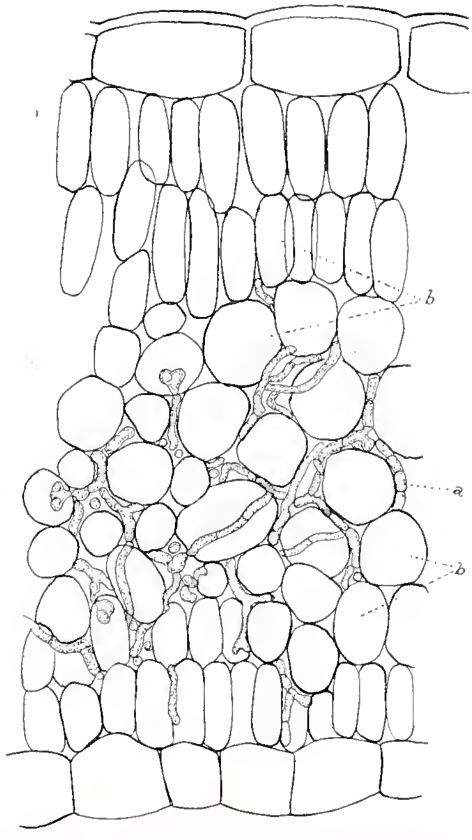


Fig. 2. Greatly enlarged cross section of carnation leaf affected with an internal fungus, the carnation rust. The mycelium (a) grows wholly within the leaf between the cells (b). Only the spores appear at the surface.

(Drawing by H. Hasselbring of the Illinois Experiment Station.)

2. *Internal fungi*—downy mildew of grape, scab, fruit rots, canker, etc.—which continue their development wholly within the tissues of the parts attacked and which are thus prevented from developing only by destroying the germinating tube of the fungus before it penetrates the skin. (Fig. 2.)

Physical Properties of Mixtures.

In order to know just how to use and apply the different spraying liquids now in common use, it is necessary to understand and appreciate their physical properties, their behavior in the tanks, in the pump, at the nozzles and on the plants. To do this most conveniently, spray mixtures may be divided, irrespective of their insecticidal or fungicidal properties, into three general classes:

1. Mixtures involving the suspension of insoluble substances in water; for example, Paris green and other arsenites, Bordeaux mixture.
2. Mixtures consisting of simple solutions; for example, copper sulphate solution, ammoniacal copper carbonate, sulphide of potash, different soap solutions, solutions of lye or caustic soda.
3. Emulsions or mechanical mixtures of oily or waxy substances with water; for example, kerosene and crude oil emulsions, or the kerosene and crude oil mixtures with water through the medium of the pump and nozzle, without the aid of emulsifying agents.

Mixtures Consisting of Insoluble Materials in Suspension.

In the mixtures of this first class, insoluble substances are to be suspended in water and applied while in suspension. It is important to bear this in mind, as upon this fact depends not only the method of application but also the method of maintaining the compound on the fruit or leaves, as the case may be. It is necessary that the mixing be thorough in order that the material may be equally disseminated throughout the liquid. For unless it is, the distribution of the poison or fungicide will not be uniform, and hence effective results cannot be obtained. The insoluble material is kept in suspension by means of agitating the liquid either by a separate agitator or by a devise attached to the pump handle.

Agitators Considered.

The proper and thorough agitation of sprays of this class is one of the most important points in the successful use of the materials

so used. The agitators now in common use are far from perfect and unless carefully watched are often the cause of failures. It has now come to be almost the universal custom to attach the agitating device to the pump handle, so that the liquid is stirred with every stroke of the operator. This at first sight seems a good plan. In some respects it is, for it at least secures some sort of agitation which is better than none at all. But the labor of pumping, so as to keep the pressure up to the required mark, is really heavy enough without adding to it the extra work of keeping a properly constructed agitator at work. Then, too, the two motions can hardly be coupled to advantage. For the pumping, a long, steady stroke is best, while for thorough agitation a quick, abrupt stroke is preferable. It is very much better, therefore, to have the agitating device separate from the pump. In this way a few vigorous strokes or turns of the handle accomplish a great deal better work than the slow dipping of a paddle. Agitators having a whirling paddle with tilting blades arranged somewhat like a screw propeller are, on the whole, the most satisfactory. (Fig. 3.) With this instrument the liquid is given a whirling upward motion, which very effectively dislodges the material from the bottom and sides of the tank. On the long, flat tanks now in general use it is practically impossible to secure thorough agitation throughout the liquid by any device which may be attached to the pump handle. For these tanks the agitator should consist of a set of two or three paddles so arranged that they will keep the whole body of liquid in violent motion. These paddles should be attached to a lever or handle on top of the tank. Where Paris green is used alone, the agitation must be continuous while the pumping is going on, and in order to insure its thoroughness it would pay to put on an extra man or boy to run the agitator. With properly prepared Bordeaux mixture (as will be explained later) continuous agitation is unnecessary. Merely stirring the liquid from time to

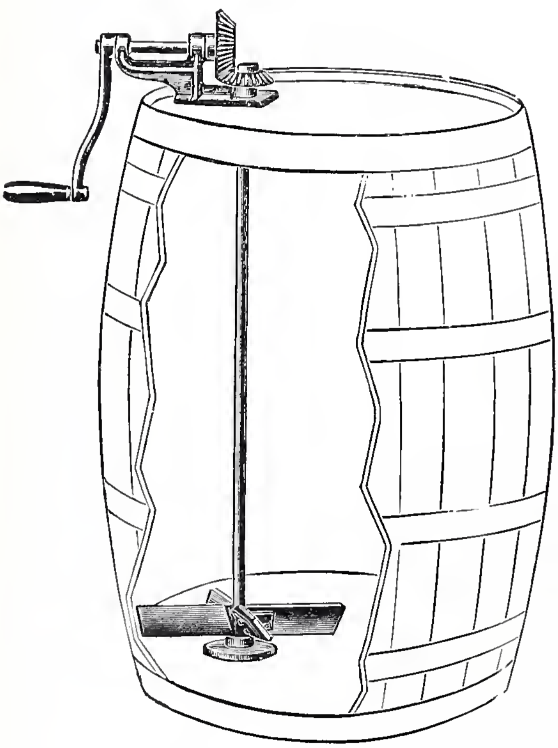


FIG. 3.

time is amply sufficient to keep the precipitate in suspension. This can best be accomplished while the rig is moving from tree to tree, thus allowing one man to do the whole work. Some growers in New York have rigged up attachments on the wheels of their spray wagons which turn the agitating device and thus do away with this extra hand labor. Where Paris green is used combined with Bordeaux mixture, the latter helps to keep it in suspension and no further agitation is needed than for the Bordeaux alone.

Proper Placing of Pumps on Barrels.

Most of the pumps are now placed on the end or head of the barrel. For use in applying mixtures consisting of suspended materials—especially Paris green—it is very much better to place the pump on the side of the barrel. When the barrel is laid down on its side, as it must be in that case, a bottom with a depression at the center is formed by the sloping sides. Most of the settling will go towards this depression and thus there will be really a smaller settling area than that afforded by the flat bottom. Moreover, the flat bottom and straight sides, when the barrel is used upright, offer some resistance to the movement of the liquid, while the sloping bottom, in the case of the barrel on its side, offers little resistance and thus aids rather than retards in the movement of the liquid. In order to see how difficult it is to dislodge a comparatively heavy substance, such as Paris green is, from around the sides of a barrel bottom, place a small quantity of the poison in a flat-bottomed tumbler and attempt to keep the material in suspension by stirring. It will be found that it requires rather vigorous stirring in order to dislodge the green from the bottom and keep it from settling around the sides. If this little experiment is performed, it will be well to note how very much more effective is a whirling motion over a simple dipping, illustrating the advantages of the whirling-paddle agitating device.

How to Spray Properly.

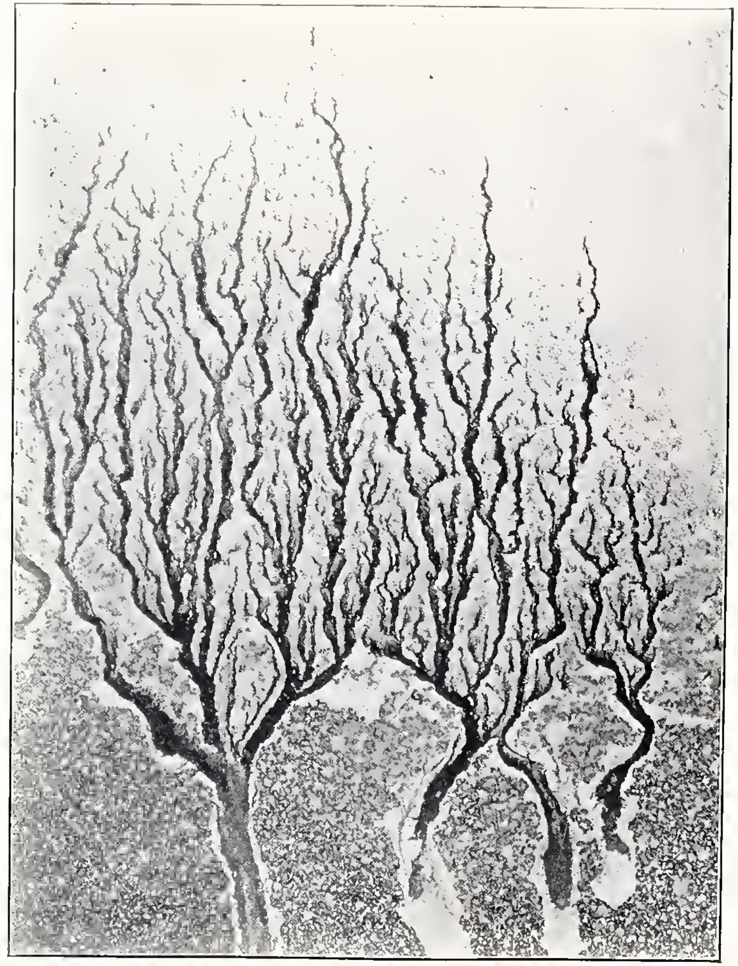
To spray properly is an art requiring both skill and intelligent care to accomplish it successfully. Moreover, it is of the greatest importance; for no matter how carefully the mixtures may be compounded or how nearly up to purity standards are the ingredients used, full success is practically impossible unless the mixtures are properly applied. It is not enough to go out with a vim and determination "to do an everlasting good job" and give everything a drenching. This is not only wasteful but positively less effective than when a smaller quantity is properly applied; for when drenching is practiced there will finally be less material on the trees, leaves

and fruit than when a smaller quantity is properly put on. To many this may seem strange. But nevertheless it is a fact, and an attempt will be made to show just how it comes about.

In order to do this it will be necessary to study in detail what takes place in the drops of water after they leave the nozzle and become attached to the fruit or leaves. It will be remembered that the material is to be kept in suspension and equally disseminated throughout the whole mass of liquid in the tank. Consequently, each minute globule of water as it leaves the nozzle will carry with it a certain amount of suspended Paris green, Bordeaux mixture, or both, as the case may be. Now, the settling which goes on in the spray tank takes place also in the globule of water after it becomes attached to the leaf or fruit. Therefore, it is desirable to have each globule of water deposit its suspended material at the place where it is attached to the fruit. But liquids have what is known as "surface tension;" that is a force exerted from within which tends to keep a small globule of water intact. Beyond a certain size this force is unable to keep the globule intact as such. Then it will not remain where it strikes the surface of the fruit or leaf, but will run down to the lowest point and there drip off. This happens when the globules are too large or if the smaller ones are brought so close together that they run together to form one or several large ones and the same running down and dripping-off results. This running-together may be easily seen by breathing against a cold window pane. First, it will be noticed that the globules of condensed moisture are exceedingly small, each one, however, remaining separate and distinct. Now continue breathing against the moist spot. The globules of moisture increase in size until a point is reached where they run together and form one large globule spread over the surface of the glass. But now, instead of remaining spread over the glass, when it is in a vertical position, the large globule runs to the lower edge of the pane, and if there is moisture enough, will drip off.

This is exactly what takes place on the surfaces of leaves and fruit when the spray liquid is applied. The globules are at first deposited as separate, fine "dew drops," covering the entire surface. This is the ideal point to be reached, and as soon as it has been accomplished no more liquid should be applied. If more is put on, the small drops run together and trickle down to the lowest point. It has been said that the settling of the material takes place in the globule of water after it becomes attached to the fruit. The larger the globule, then, the more settling will take place. It has also been seen that the settling goes to the lowest point. Consequently, if the globule is spread over a large portion or the entire surface, the settling will naturally go to the lowest place in this instance also, and as the low-

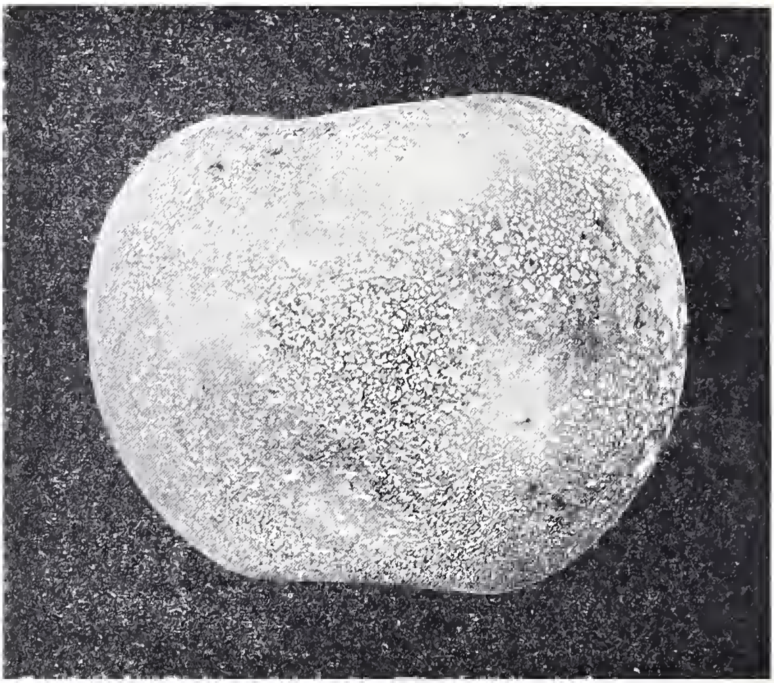
(a) Sprayed to the proper point.



(b) Sprayed too long or drenched.

PLATE III.

Glass Plates showing the effect of proper and improper spraying.
(From Bulletin 68 of the Ill. Exp't. Station.)



(a) Sprayed to the proper point.

(b) Sprayed too long, or drenched.

PLATE IV.

Apples properly and improperly sprayed.

(From Bulletin 68 of the Ill. Exp't. Station.)

PLATE V.

Apple leaves showing the results of the accumulation of the spraying material at the edges by running down and evaporating. The dark edges and spots represent dead patches on the leaves.

(From Bulletin 68 of the Illinois Exp. Station.)

est point is where the water drips off, the sediments go to that point and drip along with the liquid, thus leaving actually less material on the fruit or leaf than when a smaller quantity is properly applied. Or, if it does not drop off it will accumulate at this lowest place, often in quantity sufficient to cause injury, while the upper portions are left bare and thus exposed to attack.

Plate III illustrates the running together and settling to the lowest point. This effect was produced by spraying two glass plates, (*a*) just to the proper point and (*b*) beyond that point until the globules ran together. In (*a*) it will be noticed that the surface of the glass is uniformly covered by the dried material. But note what took place when the spraying was carried beyond the proper point. The globules ran together and the liquid flowed down in little streams and carried with it the suspended material, leaving bare streaks, and either accumulating it at the lowest point or carrying it away where it dripped off the plate.

It must be emphasized that the material must be so applied that it forms an *unbroken* thin coating over the entire surface of the leaf or fruit. This is especially true of the Bordeaux mixture. That remedy, as has been shown, is wholly preventive in its action. Any breaks in the coating are exposed to attack, and if attacked, become centers of infection, the birthplace of new crops of spores, thus increasing the chances for new infection. The more numerous the spores, then, the more carefully must the application be made, for when the spores are very abundant the chances for some of them to settle on the exposed places are correspondingly greater. Plate IV (*a*) shows an apple properly sprayed. The photograph shows the distinct marks of the separate globules of mixture. In addition, there were many exceedingly fine globules too small to be seen in the picture. Plate IV (*b*) is an example of an apple which has been sprayed long enough to allow the globules to run together and drip off or accumulate in spots. Notice how unevenly coated is the surface. In an orchard where the fruit rot or the scab is very abundant an apple or a leaf sprayed as that one shown in the plate is little better off than if it had not been sprayed at all.

The injury due to the excessive accumulation from the material running down and evaporating at the lowest points has been mentioned. Plate V exhibits examples of leaves so injured. These leaves were taken from a tree sprayed with nearly ten times the usual strength of ammoniacal copper carbonate solution until the liquid began to drip. The leaves were badly burned around the edges and at the tips, while the leaves of another tree properly sprayed, or without dripping, were not injured at all by the same solution. Thus, it will be seen, that two evils may result from improper spraying:

Large spots may be left bare and exposed to attack, and injury may be caused by excessive accumulation in a few spots.

Only a pump capable of maintaining a high pressure should be used, and for this class of work the finer nozzles are called for. The liquid should be kept issuing as a fine mist—so fine that it floats in the air as steam or smoke. This is impossible under a low pressure, for the higher the pressure the finer will be the mist, other things being equal. The pressure should always, therefore, be kept at its maximum, if possible between fifty and sixty pounds, never below forty. With the liquid issuing as a fine mist, the nozzle should be held some little distance away from the tree and the mist allowed to float in and condense itself upon the fruit and leaves in fine globules, thus completely bedewing the surfaces.

Hence the importance of the injunctions: "*Use only a fine nozzle; use pressure enough to keep the liquid issuing as a fine mist, and spray only until the fruit and leaves are completely bedewed.*"

Mixtures Consisting of Simple Solutions.

Mixtures of the second class, or diluted solutions, are somewhat easier to handle, in that the problem of agitation is absent. But they have to be considered from two standpoints and must be handled differently, depending upon whether they are used as insecticides or as fungicides, or whether for internal or external fungi. If used as a preventive against one of the internal fungi, then all the precautions regarding the maintenance of a fine mist upon the fruit must be observed. Otherwise, the two evils mentioned above—the leaving of exposed spots and the injury from excessive accumulation in spots—will result. Plate V has already been cited as an example of damage from the latter cause. If, on the other hand, the solution is used against the sucking insects or external fungi, and therefore intended to destroy by contact, a different mode of application is called for. In these cases a coarser nozzle, throwing a more or less direct stream is desirable. The effectiveness of the spray is often increased by having it strike with some force. Here the rules mentioned above, regarding the maintenance of a fine mist, do not apply. Every part of the tree should be thoroughly wetted so as to have the spray come in contact with every insect and fungus spot. In this case the spray has usually done its work as soon as it strikes. It is not important, then, to have it remain on the trees; in fact, the reverse is often desirable. Of course, when strong solutions are used, there is danger of injury from the accumulation by evaporation at the lower edges of the leaves, or if the solution is allowed to run down the trunks and thus saturate the ground around the root

crowns. It is well, therefore to avoid waste when spraying in this way, and to carry the operation just far enough to wet every part of the trees or plants.

Emulsions.

The mixtures of this class are practically all used against sucking insects; scales, plant lice, and the like. A large proportion of these mixtures is also intended for winter use, when the trees are dormant, and are, therefore, not subject to the same rules as those used when the foliage is present. A more direct stream is desirable, for here, as with the simple solutions used for a similar purpose, the effectiveness of the spray is increased by having it strike with some force. A good many of the insects of the sucking class are protected by a woolly, hairy or waxy covering, which it is hardly possible to penetrate without projecting the spray against them. The writer has sprayed the plum aphis with kerosene and water through an ordinary fine Vermorel nozzle without effect; while the same mixture put on through a somewhat coarser nozzle as a direct stream proved wholly effective.

When kerosene and water or the crude oil and water are used the nozzle must not be too coarse. The mixing of the oil and water is accomplished at the nozzle. If the nozzle is too coarse, therefore, the mixing will not be thorough. The aim in the use of this class of mixtures is to secure a thin coating of oil over the tree—the thinner the better. For this reason the spray must reach and wet every part. It is not necessary to maintain the separate globules intact. Therefore, it is not so difficult to apply this class of sprays properly. Excessive dripping must be avoided, and the mixture of oil and water must not be allowed to run down the tree trunks, or to accumulate in the crotches of branches. In the one case the root crown may be injured; in the other the bark in the crotch may be killed and thus allow the entrance of disease spores to the heart wood. Spraying should proceed from the top downward, holding the nozzle in one place only long enough to wet that part, not until the liquid begins to run down.

Recapitulation of Spraying Directions.

To recapitulate the spraying directions for the principal mixtures in use, the following table is presented:

Paris Green and other Arsenites. Bordeaux Mixture and combinations of Bordeaux Mixture and Paris Green or other Arsenites.	Spray with a fine nozzle under heavy pressure; spray only to the point of covering the fruit or leaves with a continuous coating of fine "dew drops."
Ammoniacal Copper Carbonate. Copper Sulphate Solution. Sulphide of Potash.	When used for internal fungi, apply as directed for Paris green and Bordeaux mixture. When used against external fungi, use as directed for soap solutions and the like.
Soap Solutions. Tobacco Water. Caustic Lye Solutions.	Spray in a direct stream so as to strike with some force, using a coarser nozzle than for Paris green or the like. Avoid excessive drip and do not allow the solutions to run down the trunks.
Emulsions. Kerosene and Water. Crude Petroleum and Water.	Spray emulsions as directed for soap solutions, etc. For kerosene and water and crude petroleum and water, use a nozzle fine enough to accomplish a thorough mixing, but yet capable of projecting the liquid more as a direct stream than as a mist. Completely wet every part, but do not allow the mixtures to run down the trunks, or to accumulate in forks of branches or in deep wounds.

Purity of Materials and Proper Preparation of Mixtures.

So far, but one side of the case has been presented. There is still another important phase of the subject to discuss before all the fundamental factors leading to successful spraying results are explained. Part of these factors are beyond the control of the fruit-grower, part are within his control. The purity of the materials used and their proper preparation and combination are alluded to. These are of as fundamental importance as any of the points already mentioned. For it is obvious that unless the materials used are pure and up to standard strength, their use cannot lead to successful results, no matter how skilfully and carefully they may be applied. It will be impossible to treat of the scores of materials that have been and are used in spraying operations. Space permits only of the discussion of those substances which now constitute by far the bulk of spraying materials in general use. These will be taken up in detail and their necessary qualifications explained.*

Paris Green.

This substance, known chemically as the aceto-arsenite of copper, was first used as a remedy for chewing insects about the year 1872,* when it was recommended for use against the canker worm. A few years later, 1878 or '79, its efficacy against the codling moth was first discovered in Western New York.* Since that time its use as a poison against chewing insects has increased at an enormous rate, until at present many tons are being used for this purpose.

Paris green was first used as a pigment in painting—hence its name. As such its prime quality was its bright green color together with some insolubility in water to prevent it from being washed from painted surfaces by rains. Its chemical composition and proportion of certain chemical ingredients were therefore of secondary importance. These considerations, then, did not enter in its manufacture. With its use as a poison spray, however, its chemical composition, together with its insolubility in water, become prime requisites. A demand for a green manufactured solely for its use as an insecticide has been created, which is being met, partly at least, by manufacturers of the poison. During late years, however, there have been many complaints from users of Paris green both as to its inefficacy and its injurious action upon the foliage of trees. Upon investigation it was found that the greens prepared by different manufacturers were exceedingly variable in their composition, the results,

*For further information regarding the purity of commercial insecticides and fungicides, see Farmers' Bulletin 146, issued by the U. S. Department of Agriculture.

*Slingerland, Cornell Univ. Agr. Exp't Station, Bul. 142, p. 50.

no doubt, of so-called improvements in the method of manufacture, leading to an increased product at less expense. Paris green when pure varies both in composition and the proportions of its chemical ingredients. Add to this the variability brought about in its manufacture, and it will readily be seen how exceedingly variable and unsatisfactory a product will result.

Investigation has shown that most of the injury caused by Paris green is due to an excessive proportion of free arsenious oxid (white arsenic), either remaining as the result of careless manufacture or wilfully put in to bring up a product low in arsenic to a standard strength. Free arsenious oxid is soluble in water after a time, and when it is present in Paris green to any great extent, destroys one of the latter's most valuable qualities as an insecticide, its great insolubility in water. It is this latter quality which makes the use of Paris green possible without injury to the foliage. Free arsenious oxid is at times extremely injurious to the foliage, especially when in solution. This seems especially true in dry localities, or during dry weather having hot days followed by heavy dews or fogs at night. The arsenic seems to be more soluble under these conditions, and is dissolved by the dew and absorbed by the leaves in sufficient quantitiy to cause injury. More investigations of the subject are necessary, however, for at times it has been possible to use pure solutions of white arsenic without injury. But until it is known more definitely under what conditions the solutions may be used, it is safer to stick to the insoluble material.

The other complaint entered against Paris green, its ineffectiveness, was found to be the result of a reduced proportion of arsenic, the active poisonous principle of the material. It requires a certain amount of poison to kill an insect. Naturally, then, if a weaker green is applied, an amount of arsenic sufficient to cause the insect's death may not be present. This was really the first defect found in the manufactured poison, and led to legislation in some States—notably New York—stipulating that Paris green offered for sale shall consist of not less than fifty per cent. of arsenious oxid. This may have been responsible, to some extent at least, for the other count against the poison, its excessive proportion of free arsenious oxid, by leading manufacturers "to fill" a green low in combined arsenic, with free white arsenic. Such legislation, therefore, reached only half way. The law has lately been amended so as to state definitely, not only the total percentage of arsenic a sample should contain, but also the limit of arsenious oxid uncombined with copper. In California the limit of free arsenious oxid has been found to be four per cent., and that limit has been adopted in the law of that State.*

*(Bulletin 126, California Experiment Station.)

It is extremely important, therefore, that the fruit-grower know definitely the quality of the poison a dealer proposes to sell him. Moreover, he will do well to avoid the cheaper grades of this material. It is safe to say that the majority of them are unreliable. This has been the excuse that some manufacturers have given for the low quality of their materials. "It will not pay us," they say, "to produce a good article to go into the market alongside of the cheaper grades of poison, which the growers persist in buying simply because they are cheap." This is unfortunately true to a large extent. But once the growers appreciate the folly of this penny-wise, pound-foolish policy there can be no doubt that the low-grades will "go begging" for purchasers at any price. The manufacturers have thus shown that it is possible to make a green which will meet the requirements of spraying purposes if the growers are willing to pay for it. On the other hand, unfortunately, the manufacturers are not always above suspicion. They seem willing to put out a medium-grade article and charge first-grade prices for it under the plea that it is "specially prepared." Then, too, some manufacturers, at least are preparing two grades of poison: one for sale in States where rigid laws are in force, the other for the less exacting Commonwealths. The only safe policy, therefore, lies in the enactment of laws defining the qualities of the green to be sold and providing for the inspection and analysis of all that is offered for sale. It is with the desire to acquaint farmers and fruit-growers with the true state of affairs, and with the hope of awakening them to a realization of their full needs, that these details are entered into here.

Unfortunately, there are no simple tests which will indicate whether a Paris green is up to full strength or free from the objectionable white arsenic in the uncombined state. It requires special chemical knowledge and apparatus to determine these points satisfactorily. There are, however, a few tests which the farmer can make for himself, showing whether a sample has been greatly adulterated or not. These are given below, in addition to another which can be made by any one possessing a fairly good microscope. It is recommended that a farmer perform these simple tests upon a sample of the green which he proposes to buy, and if they fulfill these to submit the sample to higher authority for examination. If the sample fail in these preliminary tests, it is unworthy of further consideration and it should then be discarded, thus saving delay in ascertaining these same facts from some other authority.

Tests for Paris Green.

1. Paris green should be a wholly dry and impalpable powder. If the sample feels gritty when rubbed between the fingers, or if the mass clings together in cakes or lumps, it is impure and unworthy of further trial.

2. Color Tests.—The color alone can be depended upon to determine whether a green has been wilfully adulterated or not. Pure Paris green has a decidedly bright, light emerald-green color. Any sample which presents a dull, pale or faded color is impure. By placing a small quantity in, say, a homeopathic vial, and tapping the latter gently on the bottom or sides, adulterants can often be made to separate, and can then be seen as white or light streaks or patches against the side of the vial. A pure sample will remain bright green against the glass. Woodworth, of the California Experiment Station,* has devised the following simple but effective test in connection with the color test: Place a small quantity of green, what one can easily pick up on the point of a pen knife, upon a piece of window glass which has been polished clean and dry; tilt the glass at a slight angle and gently tap the edge, just enough to cause the green to flow in a streak across the glass. If the green is of good quality, the streak will be a bright, light emerald-green; if the sample has been adulterated, the streak will have a faded, dull or whitish appearance. Any samples, therefore, which exhibit the latter have been adulterated or are of too low a grade to be used.

In connection with this test the writer has found that if great care is taken in cleaning and polishing the glass and the green is allowed to flow only gently across the surface, then by blowing strongly and quickly across the surface of the glass, from the side, in the direction of the streak, the particles of Paris green can be blown off the plate, leaving only the adulterants adhering to the glass. If they are present in large quantity they may then be seen as a dull streak by looking through the glass towards a bright window or a strong light. When the green is exceptionally pure the streak will be nearly imperceptible to the naked eye. With the aid of a compound microscope the character of the adulterants may be determined. In performing this test, great care must be exercised in blowing across the glass. The blowing must be a quick, strong puff, otherwise moisture will be condensed and the particles of green will thus be retained on the glass along with the other material.

3. Ammonia Test.—Pure Paris green is wholly soluble in ammonia. Place a small quantity, say a quarter or a third of a teaspoonful in a tumbler or other glass vessel, and then pour on an ounce or two of common ammonia water. If after stirring for four or five minutes the solution has assumed a deep blue color, and remains perfectly clear, and after standing no residue settles to the bottom, the green is reasonably pure at least. But if after stirring and allowing to stand an insoluble residue remains, the sample has been adulterated and should be discarded. This test will show the adulteration of the most fraudulent kind, the addition of a foreign

*Bulletin 126, California Experiment Station, p. 12.

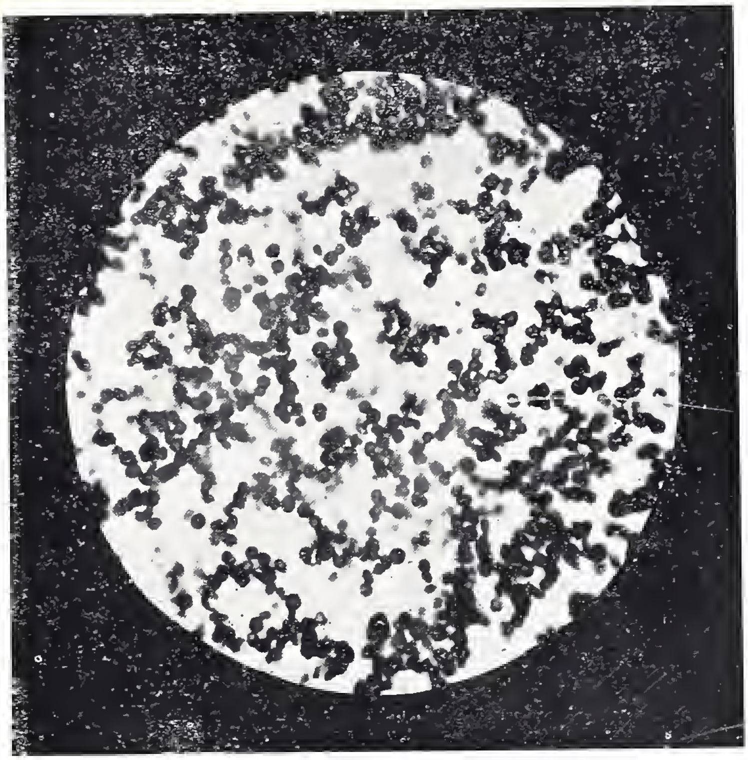


PLATE VI.
High-grade Paris green as seen under the microscope.

PLATE VII.
Low-grade Paris green as seen under the microscope.

PLATE VIII.

Bogus Paris green as seen under the microscope.

substance merely to make up bulk and weight; and any samples exhibiting such residue may be put down as fraudulently and wilfully adulterated. Unfortunately, this test does not show the presence of uncombined arsenious oxid, which is also soluble in ammonia, and which, although it has not been considered strictly an adulterant on the ground of its poisoning qualities, nevertheless its presence in large quantity is dangerous to the foliage and ought to be known.

4. Microscope Test.—This test, unfortunately within reach of only those in possession of a fairly good compound microscope, is one of the surest and quickest means of determining the grade of a sample of Paris green. The value of this test as a quick means of determining the fitness of samples for further examination, and as an adjunct to chemical analysis, was early insisted upon by the California Station, and wherever this test can be performed it will prove of great value and assistance, if only as a preliminary survey to a chemical analysis.

Pure Paris green under a one-quarter or one-sixth inch objective is seen to consist of clean, green spheres, wholly separate and distinct from one another; and in a pure sample these are all that can be seen. Plate VI is a reproduced photo-micrograph of a high-grade sample. A low-grade sample will have something of the appearance shown in Plate VII. The clean, green spheres are in this case mixed with particles of a crystalline structure, varying in shape and size. The appearance of such a sample indicates the addition of free arsenious oxid put in to fill or make up a green low in combined arsenic. The pure green can in this case be as distinctly seen among the particles of white arsenic under the microscope as "wheat can be distinguished from dirt that might be mixed with it.* When the white arsenic has been put in during the process of manufacture (as is sometimes done) or results from careless manipulation during manufacture, it is much more difficult to detect it. In that case the white arsenic crystals are often seen sticking to the green balls themselves, giving them, on the whole, a rather irregular outline and causing them to cling together into masses instead of remaining separate and distinct from one another.* For this reason, therefore, a chemical analysis must be resorted to in order to determine these points with certainty.

But there can be no mistake about the appearance of a wilfully adulterated sample. Plate VIII shows the appearance of such a sample under the microscope. In this case a great number of long, needle-shaped crystals are seen. They are the characteristic crystals of gypsum (calcium sulphate) and there can be no legitimate excuse whatever for their presence. These, together with the preponderance of the other irregular crystals and the almost total absence of

*Bulletin 126, California Experiment Station, p. 14.

the clean, green balls, brand this compound as fraudulent, and it cannot be named anything but "bogus," although the package in which it was bought was labeled "Strictly Pure Paris Green."

Requirements of a Good Paris Green.

The points which go to make a good Paris green have been summed up as follows:†

"1. It should be a wholly dry and impalpable powder. Grittiness and caking are evidences of adulteration.

"2. It should have a bright, light emerald-green color, which should not whiten or become dull in the streak left in passing a sample across a clean glass plate.

"3. It should be entirely soluble in ammonia. Any residue is an adulterant.

"4. Under the microscope it should be seen to contain only a trace of foreign matter, and should consist of clean, green spheres, wholly separate from one another. Aggregation into masses is evidence of careless manufacture.

"These are all the points which can be readily determined. In addition to the above, should be added the most important point, but one which can be determined only by a chemical analysis, viz:

"5. Paris green should contain not less than fifty per cent. of arsenious oxid, of which not more than four per cent. should be in the free state, or uncombined with copper."

Effect of the Addition of Lime.—Lime is now being added to the mixture of Paris green and water to lessen the injurious action of the uncombined arsenious oxid. This it does by combining with the soluble arsenic to form the insoluble arsenite of lime, which is fully as harmless as Paris green itself. This is true only up to a certain point, however. When the uncombined arsenic is present in large quantities the lime will do no good, and may even be harmful. It has been shown* that lime acts upon white arsenic in such a way when it is in suspension in water that the injurious action upon the foliage is greatly increased.

Objections to the Use of Paris Green.

The most serious objection to the use of Paris green as an insecticide, outside of the counts against it enumerated above, due to the shortcomings of the manufacturers, is the rapidity with which it settles in the spray tank. Paris green is a very heavy-grained substance, and therefore one requiring continuous effort to keep it in suspension. When the poison is used alone the water throughout the tank must be kept in motion. Merely creating a current around

†Bulletin 68, Illinois Experiment Station, p. 175.

*Bulletin 10, Iowa Experiment Station, p. 411; also cited by Woodworth Bulletin 126, California Experiment Station, p. 12.

the pump will not suffice. The problem of sufficient agitation is thus rendered doubly important, for without more satisfactory agitating devices than those now in general use, it is extremely difficult to secure a uniform distribution of the poison. And without a uniform distribution of the poison perfectly satisfactory results are impossible: the first portion sprayed out of the tank will be too weak to do effective work, while the last portion will be strong enough to injure the leaves, or in case the agitator is very poor the bulk of the poison will remain on the bottom and sides of the spray tank.

When Paris green is used in combination with Bordeaux mixture to form a combined insecticide and fungicide, the rapid-settling objection to this otherwise valuable poison is very largely overcome. The grains of the green become mixed with the floccular precipitate of the Bordeaux mixture, and settle slowly with it. A few of the heavier or larger grains go straight to the bottom, as they all do when the poison is used alone, but the great majority remain in suspension with the Bordeaux mixture.

Substitutes for Paris Green.

The many failures resulting from the use of impure Paris green, and the prevalence of the low-grade qualities of the poison put upon the market, have led to the introduction of other insecticidal poisons for use as substitutes. These are practically all arsenites, and therefore, like Paris green, have arsenic as their active poisonous principle. These poisons seem peculiarly virulent to insect life, and this fact, together with their usual insolubility in water, make them the most valuable class of compounds for this purpose. Some of these, notably the arsenite of lime (arsenic, sal-soda and lime mixture), the arsenate and arsenite of lead, are steadily growing in favor, especially when home-made. These have been successfully used by a number of growers and unless manufacturers of Paris green are more careful to supply a reliable and satisfactory article, it is safe to say these substitutes will largely supplant Paris green in the future. The home-made mixtures possess the additional advantage of being much lighter grained than Paris green, and therefore they can be kept in suspension very much more easily. This is especially true of the arsenate of lead, which, when freshly prepared, forms a milky precipitate which will remain in suspension for a long time without agitation. In addition, the lead compounds may be used very much stronger without danger to the foliage, a fact which makes them particularly valuable for use on the foliage of the stone-fruits—notably peaches and plums—which are notoriously sensitive to sprays of all kinds.

The chief argument urged against the use of home-made poisons is the trouble and labor of preparing them, the advantage of Paris green being that it is ready to use just as it comes from the store. But the addition of lime when using the latter alone has come to be generally recommended. This really destroys the ready-to-use argument in favor of Paris green. It is only a step further to prepare the home-made poison. Why not take this step? Thus preparing a mixture of known composition and avoiding all the uncertainties of the commercially prepared article.

Several commercial substitutes for Paris green have been introduced, most of them as arsenoids, or arsenates of different derivatives. In general, it may be said of these that they are all open to the same objectionable uncertainties that Paris green is, and they may thus be put in the same catagory. The freshly prepared home-made mixtures are very much better as far as remaining in suspension is concerned; for after the precipitate is dried it cannot be reduced to a state of division equal to the floccules produced in the liquid. For this reason alone, then, the home-made preparations are preferable.

A number of preparations have been introduced under different patented trade names. Experience and examination have shown few, if any, of these possessed of exceptional virtues over the "straight" goods. As a rule, therefore, it is safest for the fruit-grower to give these special preparations a wide berth, unless their advertised recommendations are supported by the strongest evidences of chemical examination, or the strictest practical trial that can possibly be given.

Bordeaux Mixture.

This compound, discovered accidentally in France about twenty years ago, has become perhaps the most widely used spray mixture of any kind. It is by far the most effective fungicide known, as many trials in all parts of the world have demonstrated. It consists essentially of copper hydroxid precipitated from a solution of copper sulphate by caustic lime (calcium hydroxid). The copper is the active principle of the fungicide; that is, the effectiveness of the mixture in destroying a fungous disease, or preventing its development, is due wholly to the presence of the copper. Lime has been shown to possess, at best, only very weak fungicidal properties. The lime used in the preparation of Bordeaux mixture may, therefore, be considered as merely an agent to convert the copper sulphate into a less injurious copper compound. In the form of the sulphate, it is perhaps a more effective fungicide, but it is then so injurious to the foliage of growing trees and plants, unless used too dilute to be effective, that its conversion into an insoluble and therefore less injurious form, is necessary. It is for this purpose that the lime milk is used.

The materials composing Bordeaux mixture are both staple market articles, and in commerce are pure enough for all practical purposes. The sulphate is marketed both as large and small crystals, but for spraying purposes the small crystals are just as good as the large. The only adulteration which need possibly be feared is the admixture of iron sulphate—copperas. So far as known, however, copper sulphate adulterated to any serious extent has never been found in the regular market.

Lime is more variable. In some localities it is unavoidably prepared from a very poor class of rock. When such lime has to be used in making Bordeaux mixture more has to be put in than when a lime of good quality can be obtained. But the quantity of lime should never be gauged by measure alone, for it is so essential that enough be used "to neutralize" all of the copper sulphate, that the mixture should be tested with either of the two simple tests at command to determine this point with certainty. A solution of potassium ferrocyanide, yellow prussiate of potash (1 oz. dissolved in about a pint of water), is perhaps the most convenient test for determining the presence of sufficient lime. A few drops of this solution added to a mixture containing insufficient lime will produce a reddish brown discoloration, while when sufficient lime has been added no discoloration will result. In making this test it is best to dip out a small quantity in a white saucer or shallow dish. Any slight discoloration will then be readily seen against the white dish, which would not be visible if the test were made by pouring the ferryocyanide solution into the spray tank. The mixture should be thoroughly stirred before applying the test, and in order to be certain that it is, it is also best to make two tests, giving a vigorous stirring between them. The writer has sometimes found the second test to be different from the first. When the two are alike it is safe to presume that enough lime has been used. In using the ferrocyanide it must not be forgotten that it is a virulent poison. The utmost care is therefore necessary in having the bottle properly labeled and out of reach of children and careless persons. When large quantities of stock solutions are made up one test will suffice for the whole amount on hand. That is, the one test will indicate the proper proportion of lime to use for the total quantities of stock solutions prepared. Another excellent method is "to standardize" the lime milk with the copper sulphate solution by making a small quantity of test mixture. The method of making this test and standardizing as given by the writer in Bulletin 68 of the Illinois Experiment Station is as follows:

"Make up the stock solution of copper sulphate as usual, one pound per gallon of water. Slake the lime, making of it a thin paste. Now take one pint of the copper sulphate stock solution, dilute to about a gallon, and add to that small measured quantities of the

lime, testing after each addition, until the sulphate has all been neutralized. From the quantity of lime thus used the necessary dilution can be calculated to make the lime milk any desired strength. The proportion of water necessary to make the proper dilution will be equal to the difference between the required strength and the quantity of lime milk used to neutralize the sulphate, expressed in fractions of that strength. Thus, if one-half pint is used in the neutralization, and if it is desired to have the lime of the same strength as the sulphate solution, it will require one-half pint of water for each one-half pint of lime milk; therefore, the total quantity of the latter will simply have to be doubled, by adding an equal quantity of water. If only one-quarter pint was necessary to accomplish the neutralization, the total would have to be quadrupled, or three times the quantity of water added. In large-scale operations this standardizing of the lime milk will be found very advantageous, especially where the mixing is not all done by the same man. In this case, the standardizing can be done by the foreman, or head operator, and then the spray crews have simple, straight measuring to do."

Another very simple test for determining the sufficiency of lime is the so-called knife-blade test. This test consists of simply placing the end of a bright knife-blade, key or other steel object in the mixture. If too little lime has been used in the mixture the bright steel will be coated with metallic copper, or copper-plated, while if enough lime is present to combine with all the copper sulphate no such plating will take place. The making of these tests are important; for it must be emphasized that there must be no free copper sulphate in the completed Bordeaux mixture. In order to be absolutely certain of this it is best to use an excess of lime milk, which does no harm. In fact, for use on tender foliage, such as peaches and Japanese plums, it is necessary to prepare the mixture with a large excess of lime milk in order to avoid injury.

Bordeaux mixture belongs to the class of spray washes which consist of insoluble substances in suspension in water. All the precautions, then, mentioned before regarding this class of mixtures are applicable and must be observed. But in this case a good deal of the difficulty in maintaining the compound in suspension may be avoided in the preparation of the fungicide. That is, it is possible so to mix the two ingredients that the resulting precipitate will settle slowly, and may thus be kept in suspension with a minimum effort of agitation. Plates IX and X exhibit the effects of different methods of preparing Bordeaux. The photographs were taken after allowing the mixtures to settle twenty minutes and one hour respectively. The mixture in the left-hand cylinder was prepared by mixing dilute copper sulphate solution and dilute lime milk together. The right-hand mixture was made by mixing the concentrated solu-

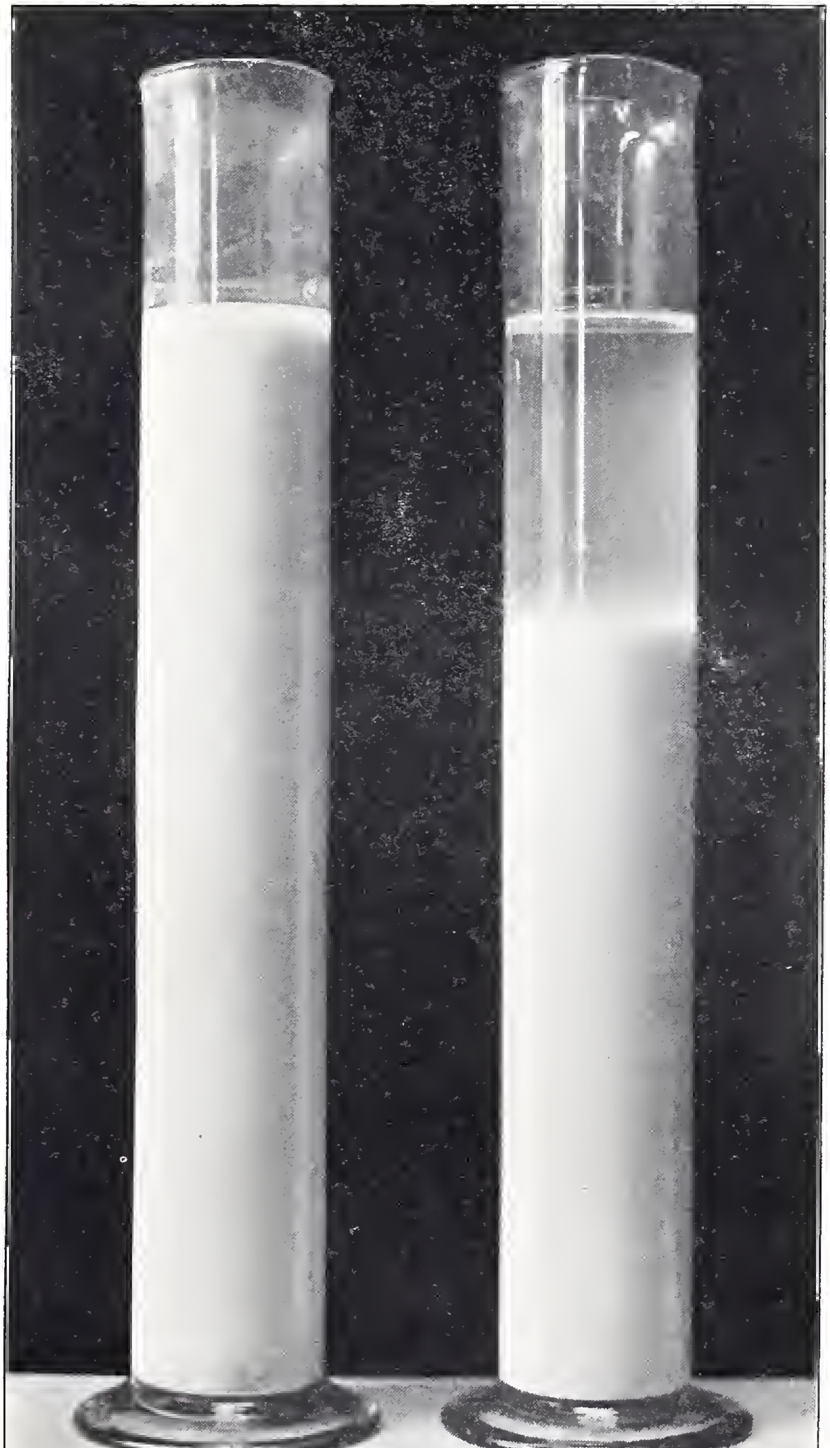


PLATE IX.

Properly and improperly made Bordeaux Mixture, after settling twenty minutes. (From Bulletin 68 of the Ill. Exp't. Station.)

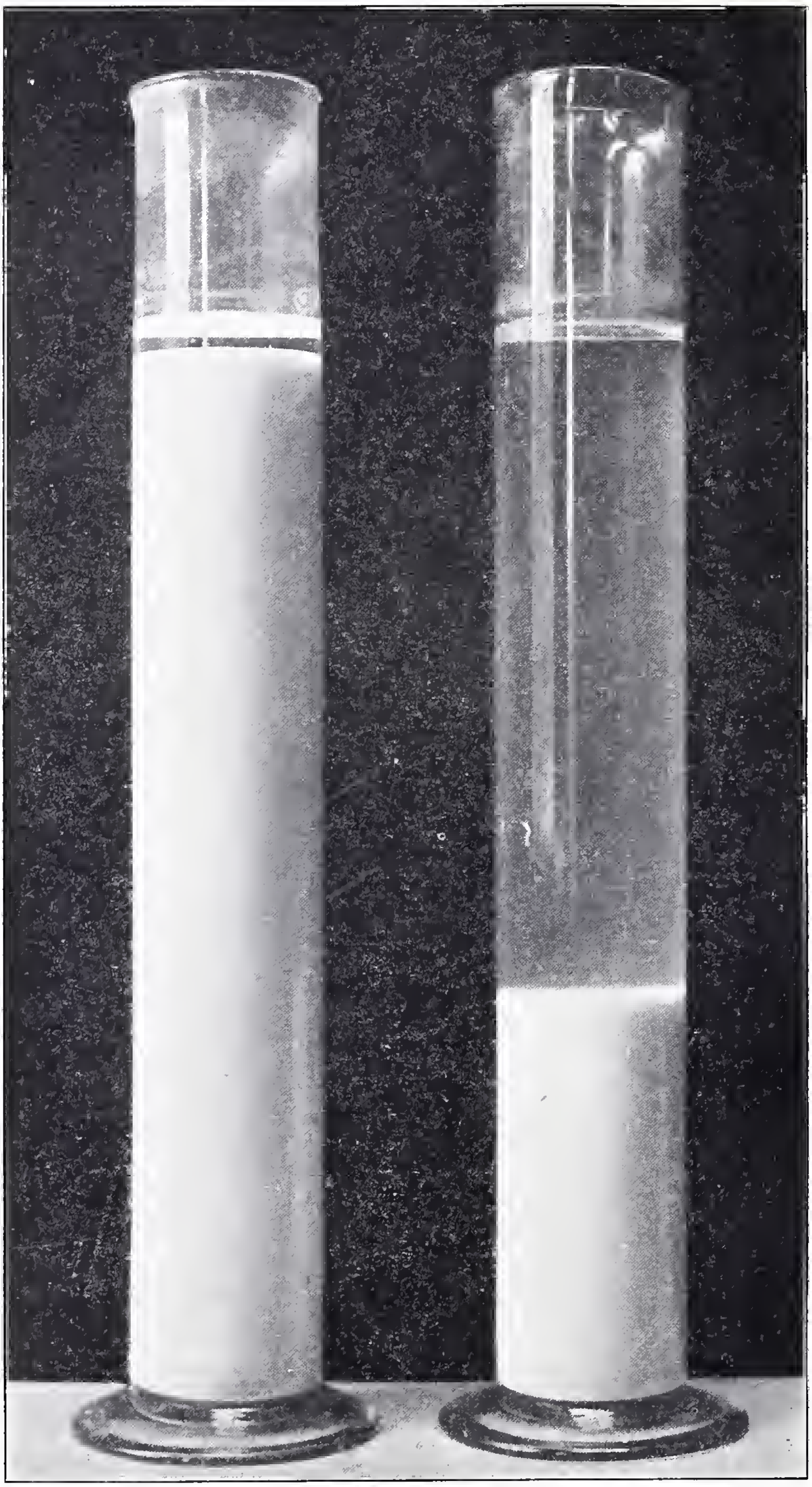


PLATE X.

Properly and improperly made Bordeaux Mixture, after settling one hour. (From Bulletin 68 of the Ill. Exp't. Station.)

tions together, and then diluting. That is, the diluting was done before mixing in one case; in the other, after mixing. The vast differences in the rates of settling are well shown by the pictures. In the properly prepared mixture there was practically no settling at the end of twenty minutes, while the improper preparation gave a mixture which settled approximately one-third of the total column in the same time, as shown by the clear liquid above the sediment. At the end of one hour the properly prepared Bordeaux showed less than an inch of clear liquid on top, indicating only a slight settling; the improperly prepared showed nearly two-thirds of the column clear. The importance of these differences in practice are at once apparent. A mixture such as that in the left-hand cylinder does not need continuous agitation; simply stirring thoroughly every five or ten minutes, or a few turns of a separate agitator while moving from one tree to another, will be amply sufficient. For the mixture prepared in the other way, continuous agitation would be necessary to insure a uniform distribution of the remedy.

Moreover, the compound formed when the concentrated solutions are mixed is without doubt different in its chemical make-up, and in all probability has not the same fungicidal value as has that made with the diluted solutions. Just how this is, however, has not been fully worked out. From the standpoint of its physical properties alone, the heavy flaky—"curdled"—precipitate is less effective as a fungicide. In the first place it cannot be so easily applied; in the second, the flakes do not adhere so well, and in the third the coating of the mixture will not be as complete as when the precipitate is finer grained.

Bordeaux mixture should never be made with hot solutions. This applies especially where the copper sulphate is dissolved in hot water, or when freshly slaked lime is used. The writer has found that the mixture made with cold solutions is even very much better than when only moderately warm. Thus, for instance, quite a marked difference was observed when the solutions were mixed at 60 degrees (F.) and at 80 degrees (F.). The 60-degree solutions gave a mixture with very much better "staying-up" qualities than the 80-degree. When the hot solutions are mixed a different precipitate is formed, the dehydrated or anhydrous black copper oxid. This precipitate settles very rapidly, and upon that score alone, is to be avoided.

Nothing but fresh or quick lime should be used. (Air-slaked lime is very unsatisfactory and should never be used. It yields a mixture which settles rapidly, and which is, moreover, mixed with heavier particles of carbonate of lime. The compound is, therefore, quite different from the properly prepared Bordeaux mixture. The lime should be carefully slaked by adding to it just enough water to keep it moistened and prevent it from "burning." If the slaking is care-

fully done and the lime is of good quality, a smooth paste with very little grit will be formed. The lime paste may be made in quantity and kept during the entire season if care is used to keep it covered with water or means used to prevent it from drying out. If it is allowed to become dry, it will not work up smooth, and a lumpy, gritty milk will result.

The question has often been asked whether it makes any difference whether the lime or the sulphate is first put into the tank; that is, if it makes any difference whether the lime is poured into the copper sulphate or vice versa. Investigations at the Vermont Station* have shown that Bordeaux mixture prepared by pouring dilute copper sulphate solution into dilute lime milk, stirring vigorously all the while, or by pouring the solutions together into the tank, remains in suspension better than that made by pouring the lime into the sulphate solution. The results of the work done at that station tend to show also that the Bordeaux so prepared possessed better fungicidal properties when used upon potatoes.

Bordeaux mixture should be used only while fresh. If allowed to stand for some time—say from one day to another—the precipitate changes in such a way that it will not remain long in suspension. This increases the difficulties of agitation. It is probable also that the fungicidal value of old Bordeaux mixture is different from that freshly prepared. But the rapid settling seems to be the most serious objection. Lodeman* cites a case in his experience where Bordeaux mixture several weeks old was successfully used on apple trees by using extra precaution to keep the precipitate in suspension. All other experience seems to indicate, however, that the freshly prepared mixture is by far the most effective.

Mixing Outfits.

Where a large quantity of Bordeaux mixture is prepared a special mixing outfit will greatly facilitate the work and will be found well worth the expense of constructing it.

The most successful of these outfits in operation consist of a system of elevated tanks, so placed that the solutions may be run into a third tank to form the mixture, and from the last into the spray tank. For this purpose a series of tiers of three platforms, each higher than the other, should be constructed. On the top one should be placed the barrels holding the stock solution of copper sulphate and lime milk. On the second platform should be placed two diluting tanks, each with a capacity of a little more than one-half the total quantity of Bordeaux to be prepared at one time. On the lowest platform the mixing tank is to be placed. This tank should be large enough to hold a full charge of mixture for the size of tanks used.

*Vermont Agricultural Experiment Station, 9th Annual Report, 1895, pp. 88-98.
*The Spraying of Plants, p. 132.

If water under pressure is available, all the better; if not, a pump throwing at least a two and one-half inch stream should be provided to raise the water to the highest tanks. In using such a system the mode of procedure would be somewhat as follows: The lime is first slaked, best perhaps on the ground in a box for the purpose. In the upper barrels the stock solutions are made to the required strength. From these the proper quantities are run into the diluting tanks below. Then water is pumped in to dilute the two solutions each to about one-half the total quantity to be made. After thorough stirring, these are in turn run into the mixing tank through cocks so placed that the streams of copper sulphate and lime come together as they fall into the tank. After thorough stirring and testing the mixture is ready to be run into the spray tank. Of course, the lowest tank should be placed somewhat higher than the spray tank to allow the completed mixture to be conveniently run in.*

Before closing this discussion of the preparation and use of Bordeaux mixture, it is well to call attention to a few minor details, which, though apparently of little consequence, go far to lessen the drudgery of spray work, and to that extent at least assist in securing good results.

In the first place, the lime milk should be carefully strained. The writer fully realizes that it is no easy task to strain large quantities of milk of lime; but he is at the same time convinced that some considerable effort in this direction will be found well expended and may save much vexatious clogging of the nozzles. The strainer should have not fewer than twenty meshes to the inch, and should be of brass wire. (Iron would be quickly corroded by the copper.) The strainer should also be made as large as possible—large enough to fit over the entire head of an open barrel. If the straining surface is thus made large, the straining will be comparatively easy and rapid. For extra safety the completed mixture may be strained as it is run into the tank.

When the spray tanks, barrels, pump and apparatus are to stand unused for a time, they should be thoroughly cleaned by washing and running through a few gallons of cheap vinegar to remove all clinging particles of Bordeaux mixture. If these particles are allowed to remain and dry, they form scales which become loosened the next time the apparatus is used, and cause most vexatious and discouraging delays.

Ammoniacal Copper Carbonate Solution.

This spraying compound ranks very high as a fungicide, being surpassed in effectiveness only by Bordeaux mixture. It is particularly valuable for use when late applications have to be made, where the

*For a more detailed account of a mixing outfit successfully used in a large apple orchard, see Bulletin 68 of the Illinois Experiment Station, page 181.

stain left by Bordeaux mixture would be objectionable. The solution when properly prepared is perfectly clear and of a very light blue color, which, however, is practically invisible after it has dried upon the leaves or fruit. For the very late spraying of peaches and plums against the brown ripe rot it is especially valuable.

The materials for preparing the solution are copper carbonate powder and commercial ammonia. The first needs no comment, for it has not been found adulterated so far as known. If one cares to take the trouble, however, the powder can be prepared at home at about one-third the cost of the commercial article. The following method of preparing the chemical has been given by Chester in the Annual Report of U. S. Com. Agric. for 1890.†

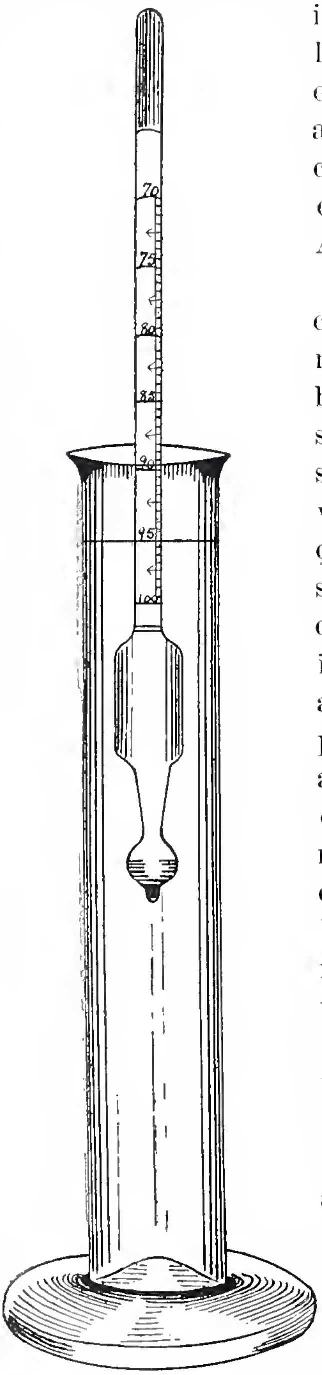


FIG. 4.*

"Dissolve in a barrel twenty-five pounds of copper sulphate in hot water. In another barrel dissolve thirty pounds of sal-soda. Allow both solutions to cool; then slowly pour the solution of sal-soda into the copper sulphate solution, stirring the same. Fill the barrel with water and allow the precipitate of copper carbonate to settle. Upon the following day siphon off the clear supernatant liquid, which contains most of the injurious sodium sulphate in solution. Fill the barrel again with water, and stir the precipitate vigorously into suspension; again allow the precipitate to settle, and again on the following day draw off the clear liquid. The operation washes the carbonate free of most of the sodium sulphate which contaminates it. Make a filter of stout muslin by tacking the same to a square wooden frame which will just fit over the open top of the second barrel, letting the muslin hang down loosely so as to form a sack; through this filter pass the precipitate, so as to drain off the excess of water, and as the filter fills, remove the precipitate and allow it to dry in the air, when it is ready for use. The operation is not troublesome, and can be carried on in connection with other work. . . . . By using the above amounts of material there will be formed a trifle over twelve pounds of copper carbonate."

†Cited by Lodeman, "The Spraying of Plants," p. 137.
*From Bulletin 68 of the Illinois Experiment Station.

The ammonia water used for preparing the copper carbonate solution should be of the strength designated as "26 degrees Beaume," the ordinary commercial product. Of adulteration, there is little to fear. Sometimes, however, it is weak, owing to the escape of the gas from the solution (it is simply a solution of ammonia gas in water) when the vessels containing it are not tightly closed. When up to full strength the 26-degree ammonia contains about 25 per cent. of the gas, and it is upon this strength that the quantity recommended in the formula for preparing the solution is based. It should be borne in mind, however, that no more ammonia should be used than is actually necessary to dissolve the copper carbonate; the smaller the quantity, the better. Ammonia has an extremely caustic action upon the leaves and when used too strong serious injury is sure to follow. For this reason it is safest for those who make use of the copper carbonate solution to any great extent to provide themselves with a "specific gravity spindle" for testing the ammonia they intend to use. Fig. 4 represents such an instrument in use. A tall cylinder, such as shown in the drawing, is filled with the ammonia water to be tested. The spindle is then allowed to float in the liquid. The depth to which the bulb will sink will depend upon the density of the liquid. The upper stem of the spindle is graduated to show the specific gravities indicated by the different depths to which the bulb sinks in the liquid to be tested. The figure at the surface indicates the specific gravity, or relative density as compared with water, of the ammonia water being tested. The specific gravity in turn indicates the percentage of ammonia, which can be found by reference to the appended table. For example, if the spindle indicates a specific gravity of .902, by reference to the column "specific gravity" the figure opposite in the "Per cent of Ammonia" column is found to be 24.94, thus indicating that the ammonia water is practically up to strength. If the ammonia is stronger, less will be required to accomplish the solution; if weaker, more must be used. With this test, the fruit grower is enabled to determine just what strength of ammonia he has to deal with, and thus all dangerous guess-work can be avoided.

*Table Showing Percentages of Ammonia in Solutions of the Gas in Water, as Indicated by their Specific Gravities.

Specific gravity.	Per cent. of ammonia.	Specific gravity.	Per cent. of ammonia.	Specific gravity.	Per cent. of ammonia.
.960	9.51	.932	16.81	.904	24.39
.958	10.03	.930	17.34	.902	24.94
.956	10.54	.928	17.86	.900	25.50
.954	11.07	.926	18.42	.898	26.05
.952	11.59	.924	18.93	.896	26.60
.950	12.10	.922	19.67	.894	27.15
.948	12.62	.920	20.01	.892	27.70
.946	13.13	.918	20.56	.890	28.26
.944	13.65	.916	21.09	.888	28.86
.942	14.17	.914	21.63	.886	29.46
.940	14.69	.912	22.19	.884	30.14
.938	15.21	.910	22.74	.882	30.83
.936	15.74	.908	23.29		
.934	16.27	.906	23.83		

†Beaume 16° indicates .960 sp. gr.
Beaume 20° indicates .960 sp. gr.
Beaume 22° indicates .924 sp. gr.
Beaume 24° indicates .913 sp. gr.
Beaume 26° indicates .901 sp. gr.

If possible, nothing but rain water should be used in diluting the ammonia for the solution. When ammonia is added to well or spring water, a heavy floccular precipitate is apt to be formed, which must not be mistaken for undissolved particles of copper carbonate. The latter are easily distinguishable, being light greenish blue in color and somewhat flaky, while the precipitate from the water is formed in rather large, dark floccules. These floccules do no harm. The danger lies in mistaking them for the undissolved carbonate and adding enough ammonia to bring them into solution, which requires far more than plants will endure.

The solution must be made in wooden or earthen vessels and wooden stirring implements should be used. Iron vessels would be soon corroded by the action of the copper.

*Compiled from the Table of Lunge und Wernik, cited by Caldwell: "Elements of Chemical Analysis," page 173.
†Lodeman: "The Spraying of Plants," page 116.

FORMULAS.*

Mixture.	Quantities for 5 gallons of mixture.	Quantities for 50 gallons of mixture.	Quantities for 100 gallons of mixture.	To be Used Against	Method of Preparation.
Paris Green, ... **Fresh Lime,** .... **Water,**	½ oz. ½ oz. 5 gals.	4 ozs. 4 ozs. 50 gals.	½ lb. ½ lb. 100 gals.	All chewing insects—codling moth, canker worm, curculio, currant worm, leaf skeletonizer, potato beetle and the like.	Make a thin paste of the lime by slaking it with water; strain; place lime paste and Paris green in a bottle or jug and shake vigorously until thoroughly mixed; then add to full quantity of water. For potato beetles the proportion of poison may be increased to 1 lb. to 125 gallons of water.
Scheele's Green or Copper Arsenate, ... Fresh Lime, ... Water, ...	¾ oz. ¾ oz. 5 gals.	6 ozs. 6 ozs. 50 gals.	¾ lbs. ¾ lbs. 100 gals.	All chewing insects, ...	Proceed as for Paris green.
Arsenite of Lime: White Arsenic, ... Sal Soda, ... Fresh Lime, ... Water to make, ...	¼ oz. 1 oz. ½ lb. 5 gals.	2 ozs. ½ lb. 4 lbs. 50 gals.	¼ lb. 1 lb. 8 lbs. 100 gals.	All chewing insects, ...	Boil arsenic and soda in small quantity of water in an iron pot not used for other purposes, until all the arsenic is dissolved. Slake the lime making a thin paste of it; strain and add to full quantity of water; then add soda and arsenic solution, and stir for a few minutes.
Arsenate of Lead: Lead Acteate, ... Soda Arsenate, ... Water, ...	1¼ ozs. ½ oz. 5 gals.	12½ ozs. 5 ozs. 50 gals.	1¾ lbs. 11 ozs. 100 gals.	All chewing insects, ...	Pulverize and dissolve the acetate and arsenic separately in small quantities of water; add separately to full quantity of water, and stir for a few minutes. This is especially valuable on tender foliage, such as peach and plum, and can be used stronger with impunity.

*Prepared for Circular 39 of the Illinois Exp't Station, and the Annual Report of the Illinois State Horticultural Society for 1901.

FORMULAS—*Continued.*

Mixture.	Quantities for 5 gallons of mixture.	Quantities for 50 gallons of mixture.	Quantities for 100 gallons of mixture.	To be Used Against	Method of Preparation.
Kerosene Emulsion: Kerosene, ... Whale Oil Soap, ... Or Soft Soap, ... Water, ...	2 gals. ½ lb. 1 qt. 1 gal.	Stock emulsion to be diluted as directed below.			Slice the soap finely and dissolve in the water by boiling; add the boiling solution (away from the fire) to the kerosene, and stir or churn violently for from five to eight minutes, until the mixture assumes a creamy consistency. If a spray pump is at hand, pump the mixture back upon itself with considerable force for about five minutes. If no soft soap or whale oil soap is at hand, use 1 lb. common soap dissolved in the boiling water.
Kerosene Emulsion, ... Water to make, ...	3 qts. 5 gals.	7½ gals. 50 gals.	15 gals. 100 gals.	Scale insects, larger plant bugs, larvae and beetles.	Use rain water in the dilutions, if possible. If hard water is used "break" it with lye (1¼ lb. to 50 gallons) before using.
Kerosene Emulsion, ... Water to make, ...	2½ pts. 5 gals.	3⅛ gals. 50 gals.	6¼ gals. 100 gals.	Plant-lice and soft-bodied insects.	Prepare as for scale insects.
Kerosene-Milk Emulsion: Kerosene, ... Sour Milk, ...	2 gals. 1 gal.	Use as directed for the kerosene-soap emulsion.			No heating is necessary in this case. Thorough churning or pumping as directed above will effect the emulsion. This emulsion is valuable where hard water must be used, no breaking with lye being necessary.
Bordeaux Mixture, ... Copper Sulphate, ... Fresh Lime, ... Water, ...	6½ ozs. 7 ozs. 5 gals.	4 lbs. 4 lbs. 50 gals.	8 lbs. 8 lbs. 100 gals.	All fungi, especially internal fungi.	Dissolve copper sulphate in small quantity of water; slake the lime carefully, making a thin milk of it. Now dilute the two solutions each to about half the total quantity of mixture to be made; mix them together and stir vigorously for a few minutes. Test with yellow prussiate of potash solution, or knife-blade, and add more lime if necessary.

FORMULAS—*Continued.*

Mixture.	Quantities for 5 gallons of mixture.	Quantities for 50 gallons of mixture.	Quantities for 100 gallons of mixture.	To be Used Against	Method of Preparation.
Ammoniacal Copper Carbonate: Copper Carbonate, ... Ammonia 26°, ... Water to make, ...	½ oz. ½ pt. 5 gals.	5 ozs. 3 pts. 50 gals.	10 ozs. 6 pts. 100 gals.	All fungi.	Make a thin paste of the carbonate with water. Dilute one-third the ammonia seven or eight times; pour on carbonate; stir vigorously and allow to settle; pour off clear liquid. Dilute another one-third of the ammonia five or six times and add to residue left; stir and allow to settle as before; pour off clear liquid. Dilute the rest of the ammonia two or three times and add to the residue. If the ammonia is full strength this should all enter into solution; if not, more ammonia may be added until the carbonate is entirely dissolved. Rain water should be used in diluting the ammonia. The solution should be clear. Dilute to spraying strength.
Sulphide of Potash, ... Water, ...	2 ozs. 5 gals.	20 ozs. 50 gals.	2½ lbs. 100 gals.	Fungi which grow with their mycelium exposed: mildews of gooseberry and rose, and powdery mildew of grape.	Dissolve the sulphide in warm water and dilute to spraying strength. The solution loses its strength quite rapidly and should be used only while fresh.
Bordeaux and Arsenites Combined: Bordeaux Mixture, ... Paris Green, ... or Scheele's Green, ... or Arsenate of Lead, ...	Usual strength as given above.			Fungi and chewing insects.	If Paris green or Scheele's green is used, prepare the Bordeaux mixture as directed above. Wet the powder by shaking in a bottle and add to the completed mixture. Stir vigorously before using. If arsenate of lime is used, add enough additional milk of lime to the Bordeaux to make the arsenite, then add the arsenic and soda. For arsenate of lead, dissolve the lead acteate and soda arsenate as above directed and add these solutions separately to the water which is used to dilute the milk of lime; stir well and add lime; then add diluted copper sulphate solution and stir.